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Variations of AIRS CO_2 in the Polar Region

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AIRS Science Team Meeting, April 24-27, 2012

Overview

- **Motivation**
- **Data**
- **Variability of AIRS CO_2 in the High Latitudes**
  Northern Annular Mode, Stratospheric Sudden Warming

Motivation

- There are few studies of the CO_2 variability in the polar region due to limited observations.
- Variability of CO_2 in the polar region is important for it impacts climate change by modifying the radiation budget and hence the extent of snow and ice.
- Global distributed CO_2 retrievals from AIRS can be used to investigate the influence of the large scale dynamics on the polar CO_2.

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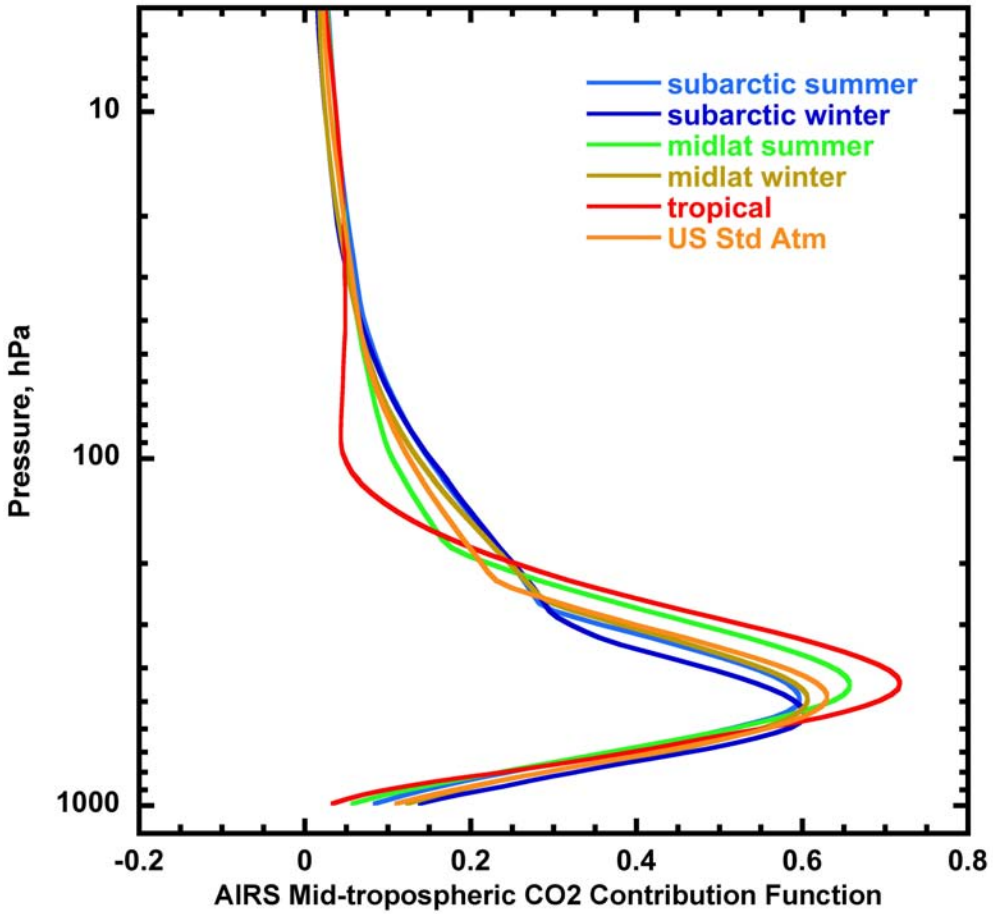
AIRS Data Sensitivity in Atmospheric Column

- **AIRS Mid-tropospheric CO_2 Sensitivity Peak: 500-300 hPa**
  (dependent upon latitude)

Chahine et al. [2005; 2008]



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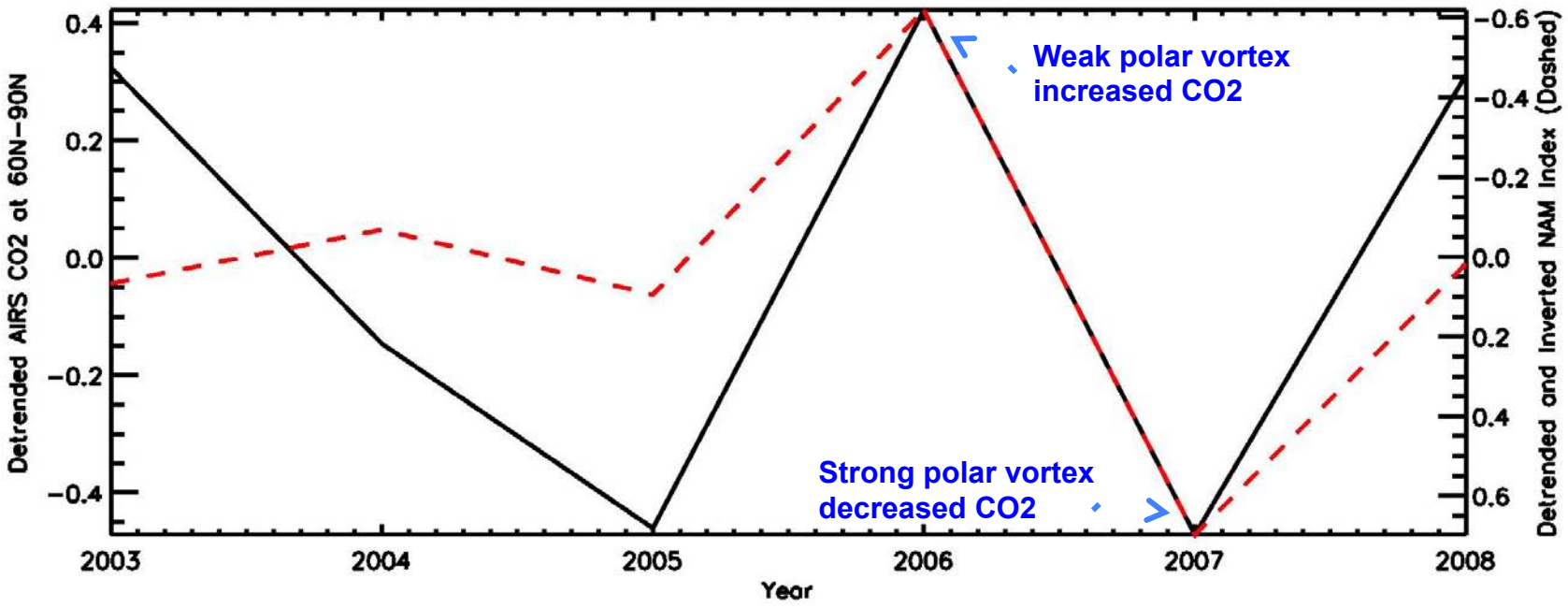
Influence of Northern Annular Mode on AIRS CO_2



Detrended AIRS CO_2 from Nov to Apr at 60N - 90N (Black)

Detrended & Inverted Arctic Oscillation Index from Nov to Apr (Red)

Correlation Coefficient = 0.74

Jiang et al (2010)

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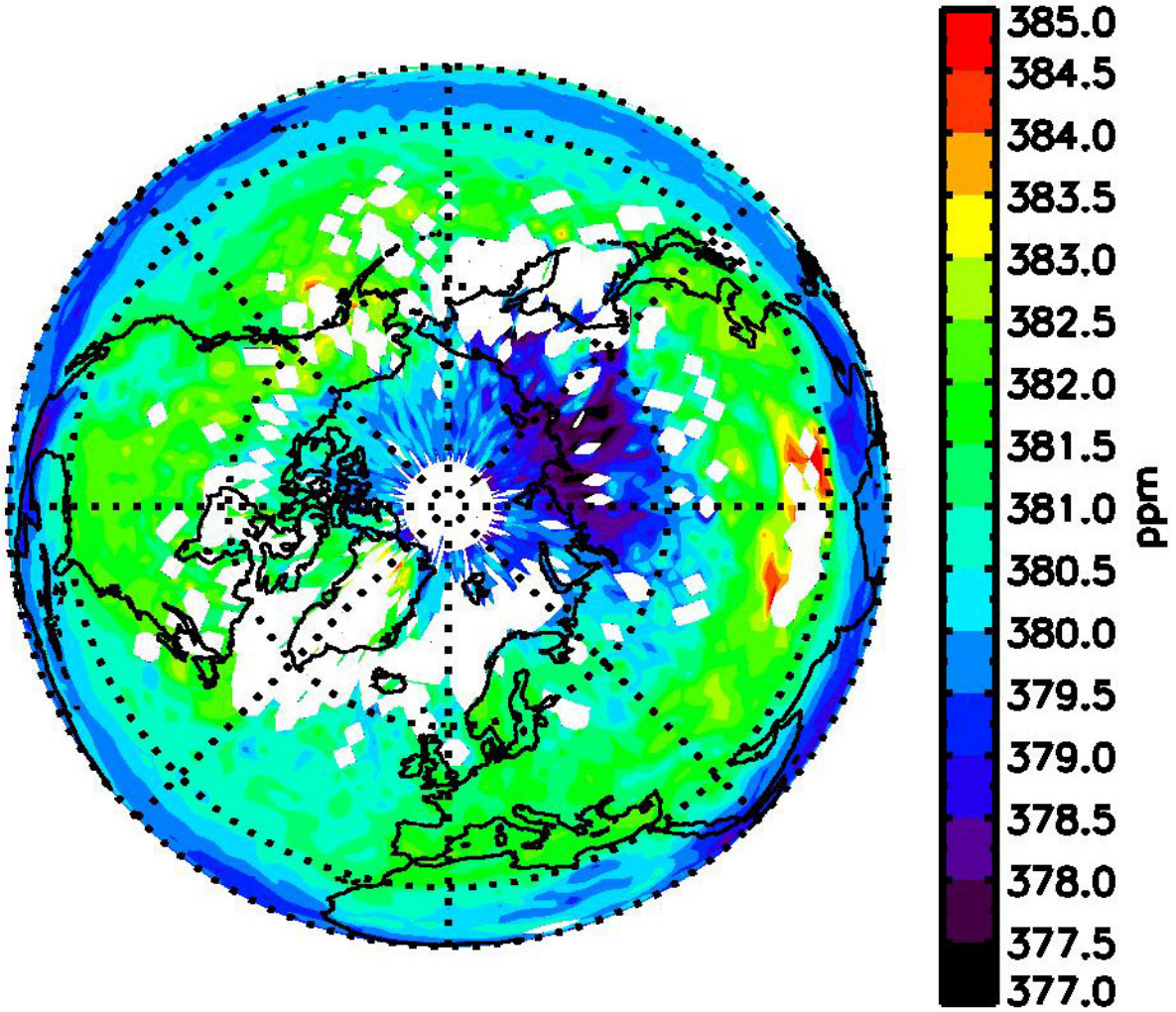
Influence of Northern Annular Mode on AIRS CO_2 (Strong Vortex)



AIRS CO_2 averaged in 2005 and 2007 (Nov-Apr)
Positive AO index; Strong Vortex

Jiang et al (2010)

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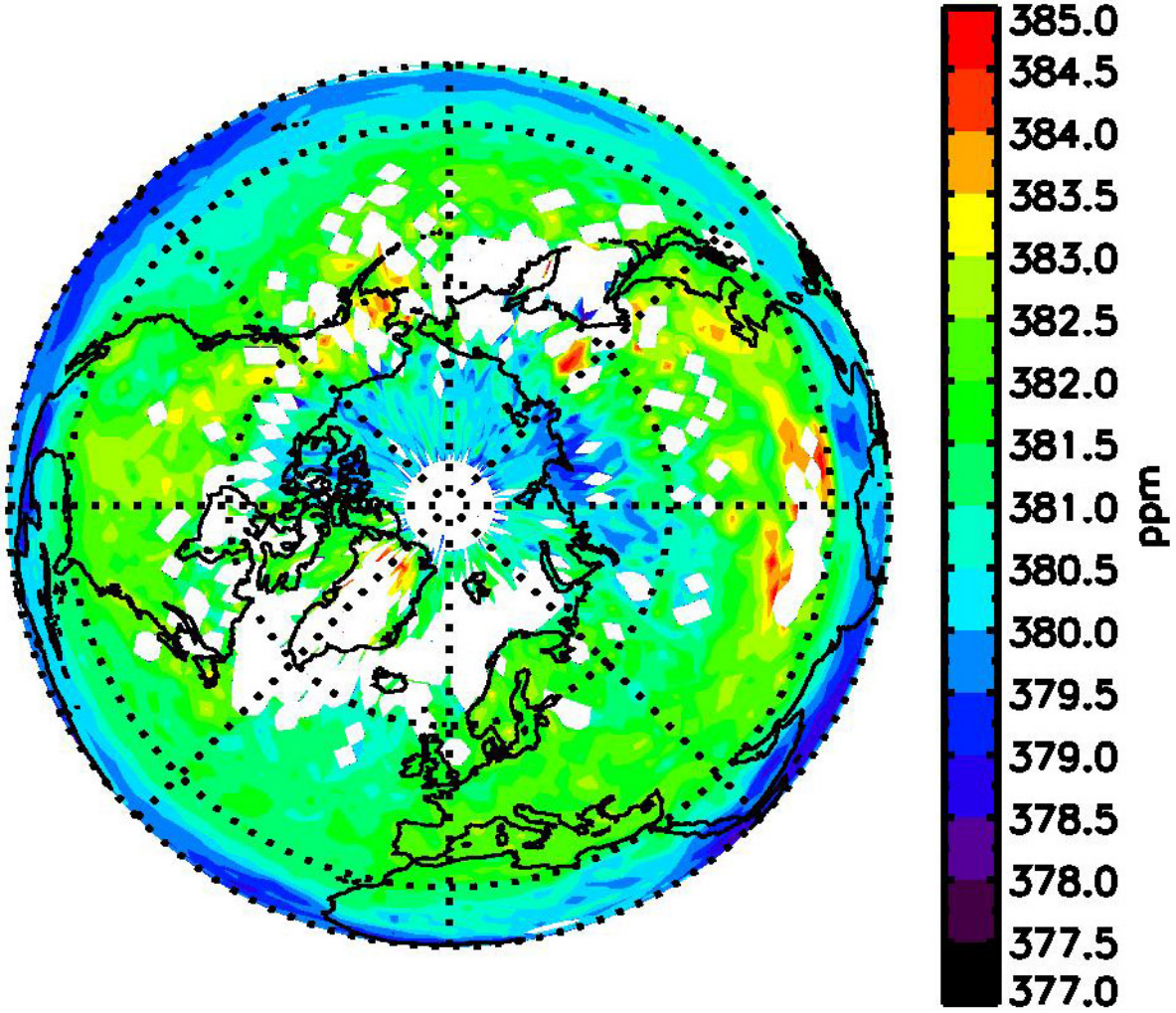
Influence of Northern Annular Mode on AIRS CO_2 (Weak Vortex)



AIRS CO_2 averaged in 2006 and 2008 (Nov-Apr)
Negative AO index; Weak Vortex

Jiang et al (2010)

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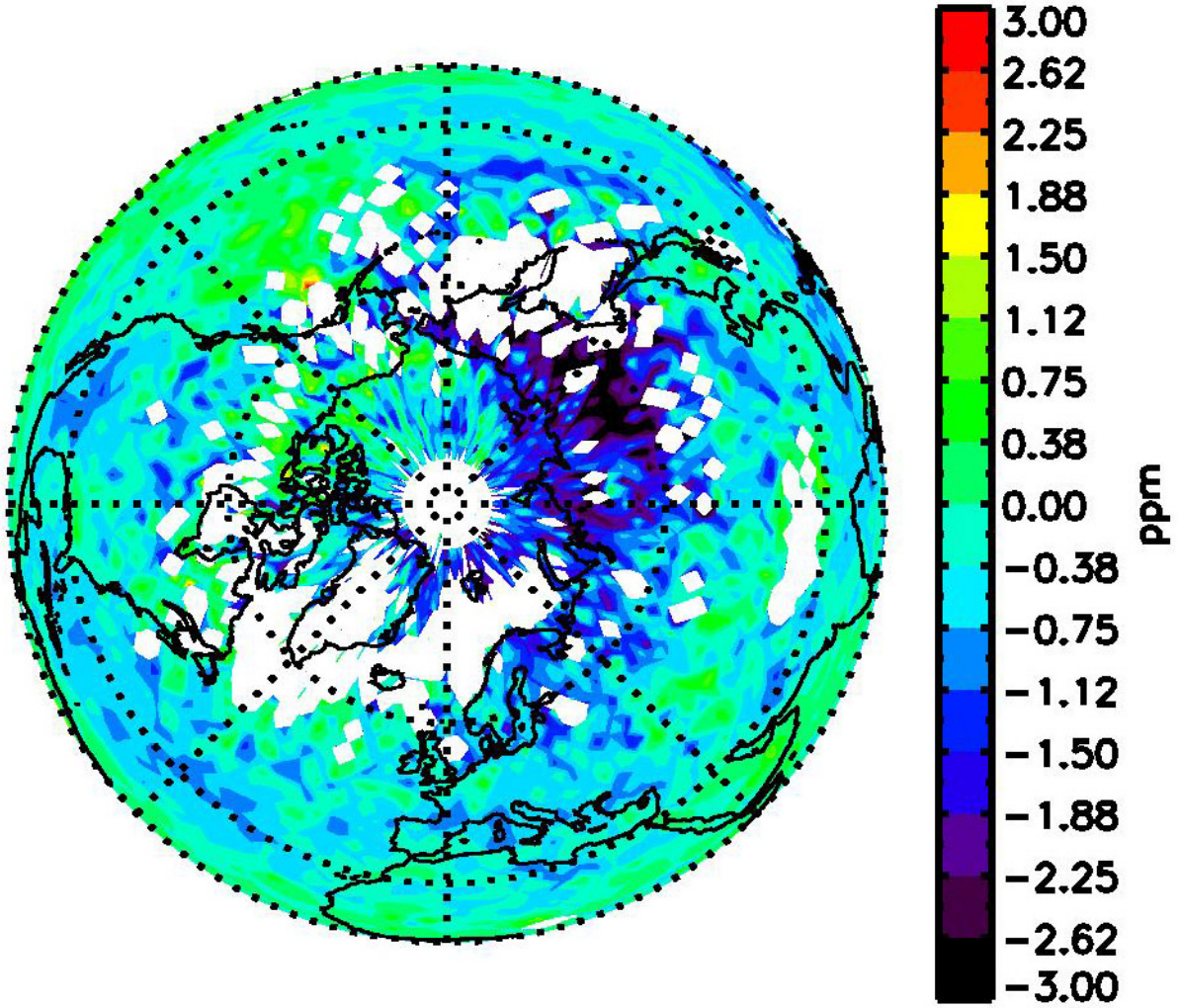
Influence of Northern Annular Mode on AIRS CO_2 (Strong/Weak Vortex Contrast)



AIRS CO_2 Difference
Strong Vortex - Weak Vortex

Jiang et al (2010)

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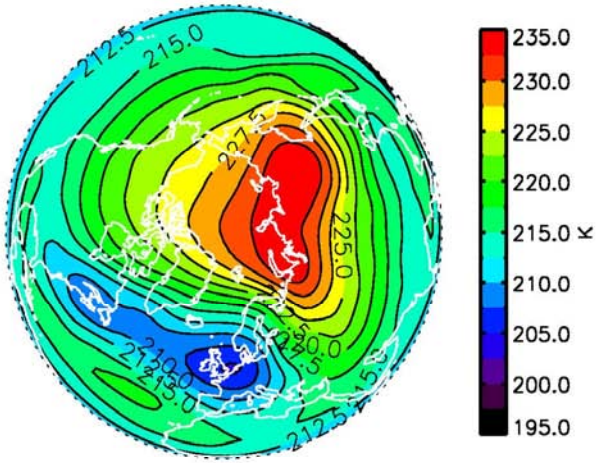
Influence of Stratospheric Sudden Warming on AIRS CO_2 (SSW of March 2005)

A stratospheric warming occurs when the latitudinal gradient in 10-hPa zonal-mean temperatures between 85°N-60°N is positive for more than 5 days. [WMO]

If the 10-hPa zonal wind at 65°N is concurrently easterly, the warming event is categorized as a ‘‘major warming’’.

Otherwise, the warming event is categorized as ‘‘minor’’.



NCEP 30 hPa mean temperature during SSW in Mar 2005

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Influence of Stratospheric Sudden Warming on AIRS CO_2 (EOF Method of Analysis)

Empirical Orthogonal Function (EOF):

The empirical orthogonal function expansion (EOF) is also known as the principal component analysis (PCA), or singular value decomposition method. The essence of EOF is briefly summarized as follows:

$$z(x,t) = \sum_{1}^{n} a_k(t) f_k(x)$$

z(x,t): real data

a_k: time series, Principle Component (PC) time series

f_k: modes of spatial pattern, EOFs, Eigenvectors of Covariance Matrix

$(C = z^T \cdot z/(N-1))$

Eigenvalue of C: the fraction of variance capture by EOF

EOF1 of GPH captures the Northern Annular Mode (NAM)

[Preisendorfer, 1988; Camp et al., 2003]

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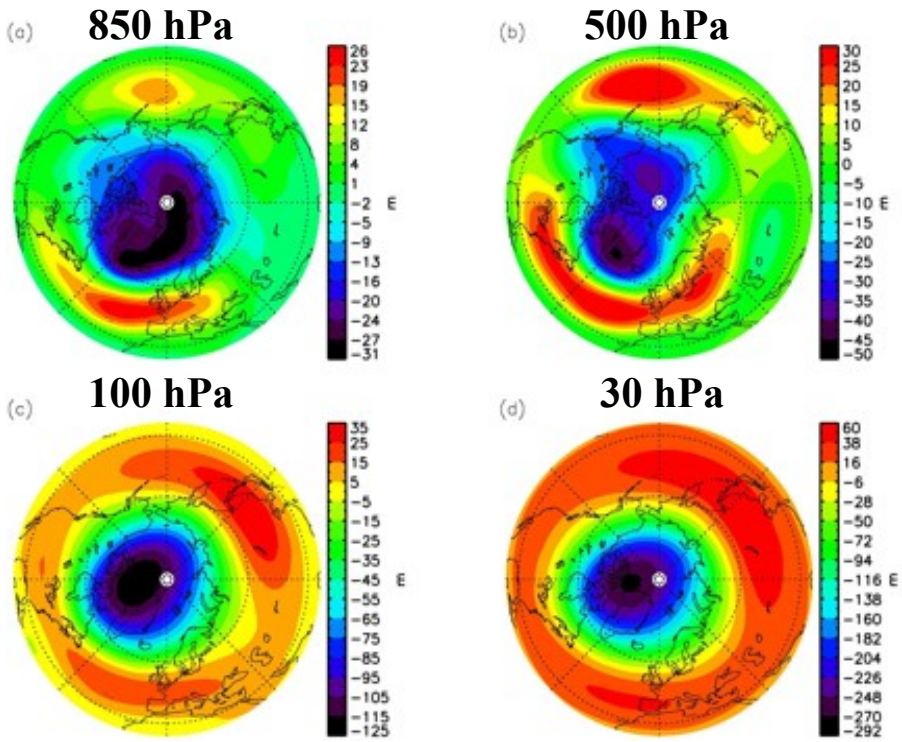
Vertical Structure of the Northern Annular Mode

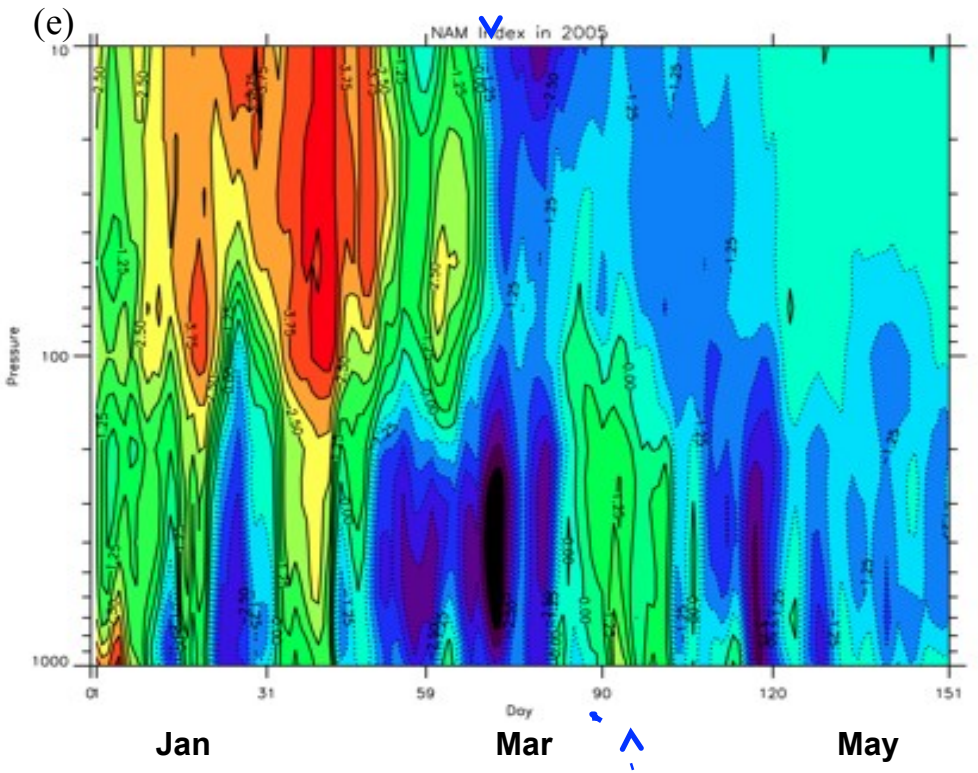
(Strength of Polar Vortex is Characterized by the NAM index)

- **Spatial patterns of NCEP-2 geopotential heights leading mode.**



- **Vertical structure of the Northern Annular Mode (NAM) index from NCEP-2 geopotential height (EOF1 of GPH)**

MARCH 17 - COLLAPSE OF POLAR VORTEX
(coupling of stratosphere and troposphere results)



polar vortex briefly reforms then collapses in final warming

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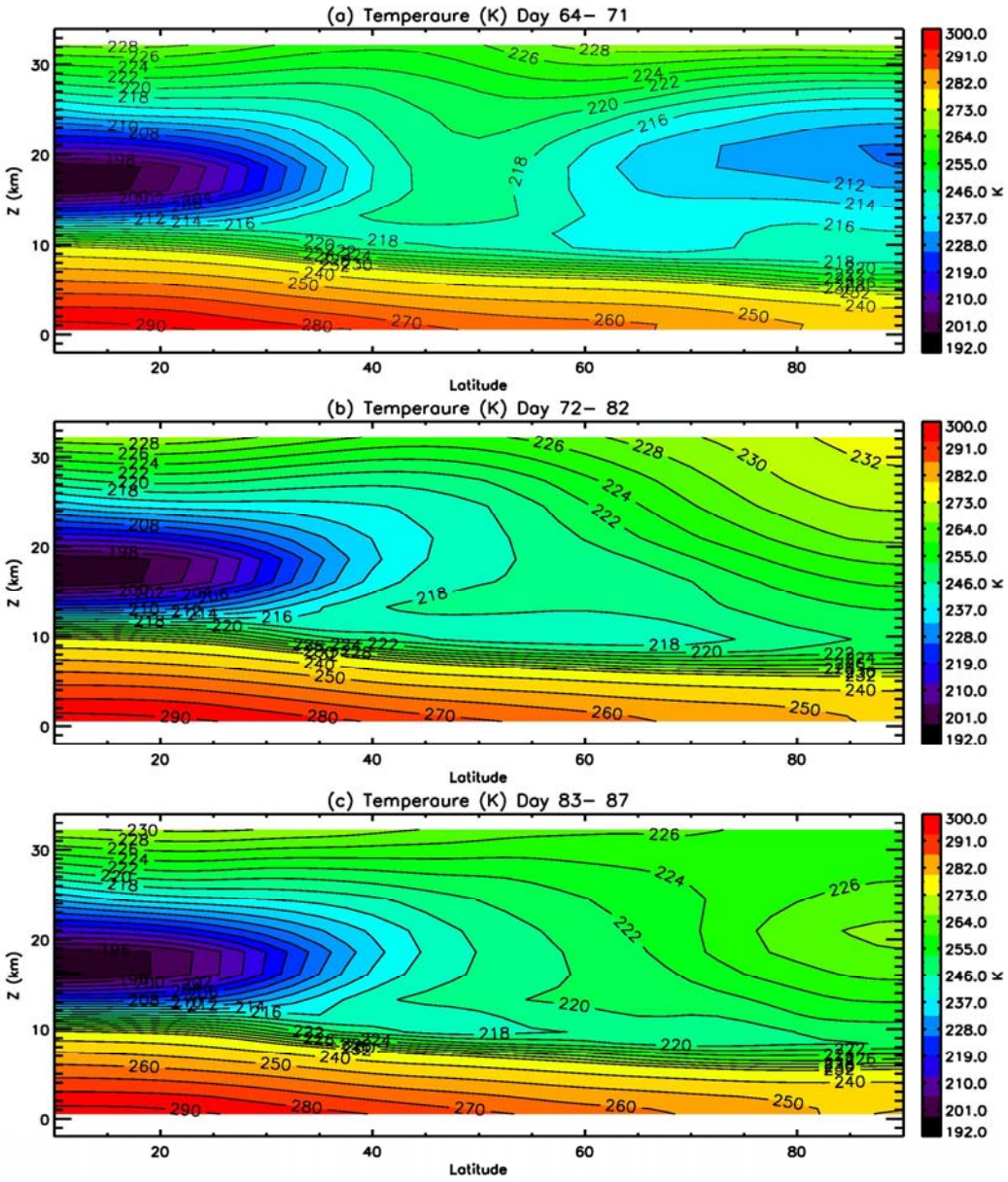
Temperature Before/After SSW

NCEP2 Temperature

Before SSW

During SSW

After SSW



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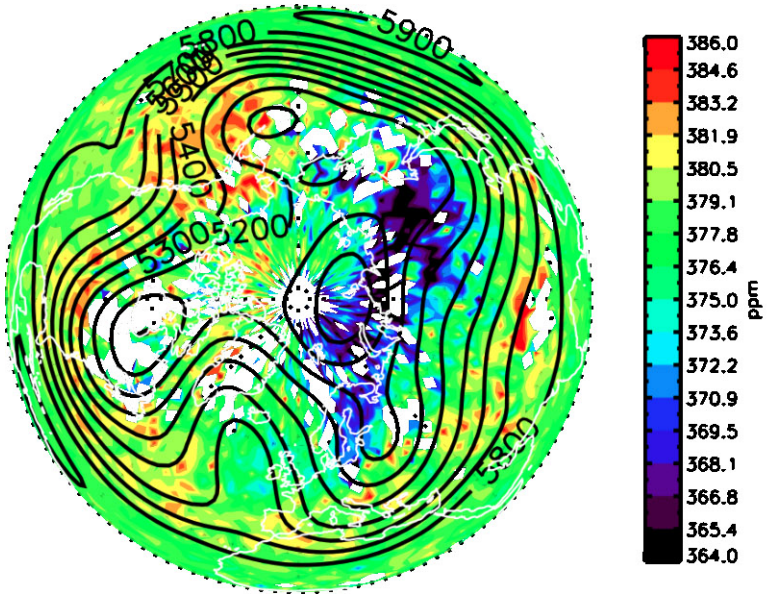
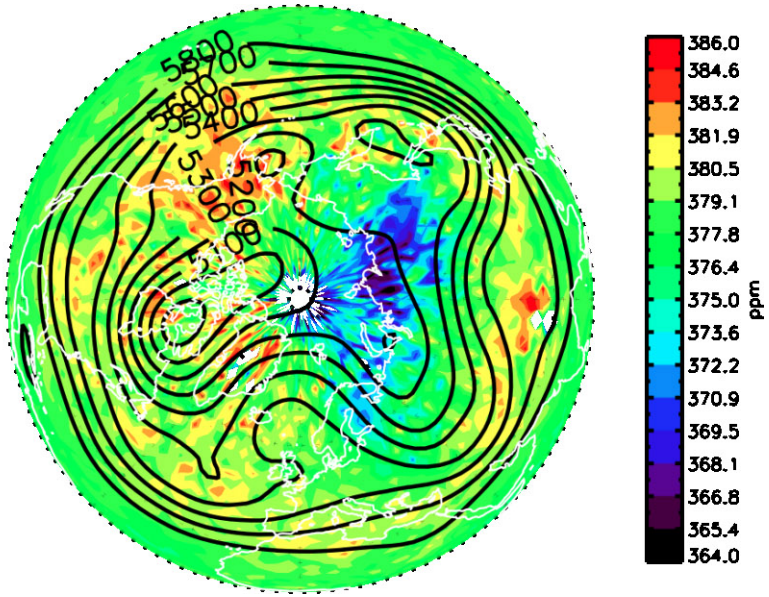
AIRS Mid-tropospheric CO_2 Before and After March 2005 SSW





Before SSW of March 2005

Vortex isolates polar atmosphere from Mid-lat atmosphere tropopause lowered

After SSW of March 2005

Polar vortex area shrinks and breaks Mid-lat higher CO2 concentrations mix into the polar regions

Conclusions

- AIRS CO_2 at high latitudes correlate well with the strength of the northern hemispheric polar vortex in the winter season.

- During the Stratospheric Sudden Warming (SSW) event, the polar temperature increases and polar winds switch from westerly to easterly. Polar mid-tropospheric CO_2 concentrations increase after the SSW in March 2005.

Thank you!